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RESEARCH MEMORANDUM

EFFECTS OF INTERNAL CORNER FILLETS ON PRESSURE RECOVERY - MASS FLOW CHARACTERISTICS OF SCOOP-TYPE CONICAL SUPERSONIC INLETS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation was conducted in the NACA Lewis 8- by 6-foot supersonic tunnel at free-stream Mach numbers of 1.49 to 1.97 at zero angle of attack to determine the effects of internal corner fillets on the pressure recovery characteristics of twin-scoop conical-type inlets utilizing boundary-layer removal and mounted on the RM-10 body. The inlet size was relatively small, with a cowl lip radius of 1.33 inches. The Reynolds number based on inlet diameter was approximately 10×10^5.

Results obtained from the investigation of these inlets indicated that without boundary-layer removal, the use of fillets resulted in substantial improvements in the pressure recoveries at and near critical mass flows at free-stream Mach numbers of 1.49 and 1.78. No significant improvement resulted, however, at a free-stream Mach number of 1.97. With complete boundary-layer removal, the fillets increased the critical pressure recovery approximately 5 percent at a free-stream Mach number of 1.97. Employing internal corner fillets also slightly increased the range of stable operation of the inlets.

INTRODUCTION

Many of the half-conical and normal wedge-type scoop inlets previously reported had sharp corners at the cowl-splitter plate or compression surface-splitter plate junctions. Apparently no literature evaluating the effects of these corners on supersonic inlet performance is available. However, during a visit to the Lewis laboratory, Dr. Fritz Feldman mentioned that the use of small fillets between the normal wedge compression surface and the cowling of a scoop-type inlet operating at a free-stream Mach number of approximately 3.0 resulted in increases in pressure recovery.

The corners at the cowl and the inlet-splitter plate junctions become more severe when the floor of a conical-type side inlet is designed to follow the surface of a circular fuselage. Therefore, the effects of fillets on the performance of a side inlet having sharp corners were determined in the NACA Lewis 8- by 6-foot supersonic tunnel through a range of free-stream Mach numbers and boundary-layer scoop heights.

Twin-scoop conical-type side inlets, with and without internal corner fillets, mounted at the station of maximum diameter of the RM-10 body (reference 1) were investigated at zero angle of attack and free-stream Mach numbers from 1.49 to 1.97. The Reynolds number, based on model length ahead of the inlets, was approximately 17×10^6. 2711

SYMBOLS

A area

h height of wedge spacer for boundary-layer removal

M Mach number

m mass flow

P total pressure

p static pressure

x distance from cowl lip, in.

δ boundary-layer thickness

Subscripts:

c projected capture area of inlet

cr critical

0 free stream

2 diffuser discharge station (17.5)

APPARATUS AND PROCEDURE

A photograph and a schematic diagram of the model, showing the twin scoop inlets mounted diametrically opposite, are presented in figures 1 and 2(a), respectively. Details of the inlets are presented in figure 2(b).

The inlets were designed so that the oblique shocks generated by the 25° half-cone centerbodies would fall slightly ahead of the cowl lips for the local Mach number ahead of the inlets of 2.06 which occurs at a free-stream Mach number of 2.0. The local Mach number was determined from a preliminary survey of the flow conditions at station 45 of the RM-10 body.

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Two cross-sectional views of the inlets, with and without 1/4-inch fillets, are shown in figure 2(b). The corner fillets were tapered from zero radius at the lip station to a 1/4-inch radius at station 1 and remained constant to diffuser station 24.5. The cowling cross section was gradually changed from a nearly sector-shaped lip of radius 1.33 inches to a circular cross section of radius 1.41 inches at diffuser station 24.5. The area variations of the inlets without and with corner fillets (fig. 3) were made identical by slightly reducing the size of the centerbody. Typical cross sections of the inlets, showing the cowling transition from the lip to the circular cross section at the rear of the inlet, are also included in figure 3.

Boundary-layer removal was accomplished by means of wedge-shaped spacers placed between the inlets and the RM-10 body, which bypassed the boundary-layer air around the inlets. From the preliminary flow survey at station 45 of the RM-10 body, the boundary-layer thickness was determined to be approximately 3/8 inch at zero angle of attack. Spacers of 3/8-inch and 3/4-inch heights, which were alined with the tips of the sweptback splitter plates of the inlets (see figs. 1 and 2(a)) were employed to obtain the boundary-layer removal parameters h/δ of 1.0 and 2.0, respectively, at zero angle of attack. The condition of $h/\delta = 0$ was obtained by placing the inlets directly on the RM-10 body. With the $h/\delta = 0$ configuration, spacers were used at the rear of the RM-10 body for alinement purposes.

All the pressure instrumentation was located at inlet station 17.5 and consisted of 18 total-pressure tubes and 4 wall static orifices for one inlet and 4 wall static orifices for the other inlet. The inlet mass flows were varied by means of remotely controlled exit plugs and were computed from the average measured total pressures at the choked exit.

RESULTS AND DISCUSSION

The experimental results of the inlets with and without corner fillets are presented in figures 4, 5, and 7 as the variation of the total-pressure recovery with mass flow ratio m_2/m_c for the three boundary-layer bypass wedges and a range of free-stream Mach number. The mass flow ratio m_2/m_c is defined as the ratio of the mass flow passing through the inlet to the mass flow in a free-stream tube area equal to the projected capture area of the inlet.

As would be expected, with no boundary-layer removal, the pressure recoveries of the inlets with and without corner fillets were relatively low (fig. 4). At $M_0 = 1.49$ (fig. 4(a)), the use of fillets did not appreciably affect the pressure recoveries at low mass flows. Near critical mass flow, however, the pressure recoveries of the inlets with corner fillets were approximately 12 percent higher than those of the inlets without fillets. At $M_0 = 1.78$ (fig. 4(b)), the pressure recoveries of the inlets without corner fillets were considerably lower than those of the inlets employing fillets throughout the range of mass flow investigated. Also, the stable operating range of the inlets was extended 2711
slightly by using fillets. At $M_0 = 1.97$ (fig. 4(c)), the use of fillets did not appreciably increase the pressure recoveries of the inlets; however, the stable operating range was extended slightly. Critical mass flow ratios of the inlets were not affected by corner fillets at any of the Mach numbers investigated.

The variation of the pressure recoveries with mass flow for the $h/\delta = 1.0$ condition is presented in figure 5 and indicates a substantial improvement in pressure recovery and mass flow characteristics compared with the $h/\delta = 0$ configuration (fig. 4). The same critical mass flows were obtained for the inlets with and without corner fillets; however, the use of fillets resulted in slight gains in pressure recoveries. The critical pressure recovery at $M_0 = 1.97$ (fig. 5(c)) increased from 76 to 81 percent when corner fillets were employed. The stable operating range of the inlets with fillets was also increased slightly.

For the inlets with fillets, not only was the level of the total pressure higher, but the velocity distribution at the diffuser discharge station was much more uniform. This is illustrated by the contour maps (fig. 6) of the measured total-pressure recoveries for the inlets with and without corner fillets operating at $M_0 = 1.97$ with h/δ of 1.0.

The pressure recovery - mass flow characteristics of the $h/\delta = 2.0$ configuration are presented in figure 7. Increasing h/δ resulted in an appreciable decrease in critical pressure recovery and a slight decrease in critical mass flow ratio. This decrease in pressure recovery is consistent with the trend reported in reference 2 which indicated decreasing pressure recovery when h/δ was increased to values near unity. The results obtained with the $h/\delta = 2.0$ configuration also indicated that improvements in pressure recoveries can be obtained by use of internal corner fillets. The peak pressure recovery at $M_0 = 1.97$ was increased $7\frac{1}{2}$ percent over that of the inlets without corner fillets.

A summary of the pressure recoveries obtained at the critical mass flows of the inlets with and without fillets is presented in figure 8. For the $h/\delta = 0$ condition (fig. 8(a)), little gain in critical pressure recovery was realized at $M_0 = 1.97$. However, at $M_0 = 1.49$ and 1.78, the critical pressure recovery was increased approximately 12 percent by employing corner fillets. With the $h/\delta = 1.0$ configuration (fig. 8(b)), a 5 percent gain in critical pressure recovery from 0.76 to 0.81 was obtained at $M_0 = 1.97$. At $M_0 = 1.49$, only a 2 percent increase in the critical pressure recovery resulted from the use of corner fillets.

Increasing the amount of boundary-layer removal to $h/\delta = 2.0$ (fig. 8(c)) reduced the gain in critical pressure recovery due to the use of fillets to $2\frac{1}{2}$ percent at $M_0 = 1.97$. At $M_0 = 1.78$ and 1.49, the improvement in critical pressure recovery due to corner fillets was 2 percent and $1\frac{1}{2}$ percent, respectively.

The addition of fillets gave substantial improvements in the inlet pressure recovery for the particular inlet-diffuser combination investigated herein.

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1. Luidens, Roger W., and Simon, Paul C.: Aerodynamic Characteristics of NACA RM-10 Missile in 8- by 6-Foot Supersonic Wind Tunnel at Mach Numbers from 1.49 to 1.98. I - Presentation and Analysis of Pressure Measurements (Stabilizing Fins Removed). NACA RM E50D10, 1950.

2. Goelzer, H. Fred, and Cortright, Edgar M., Jr.: Investigation at Mach Number 1.88 of Half of a Conical-Spike Diffuser Mounted as a Side Inlet with Boundary-Layer Control. NACA RM E51G06, 1951.

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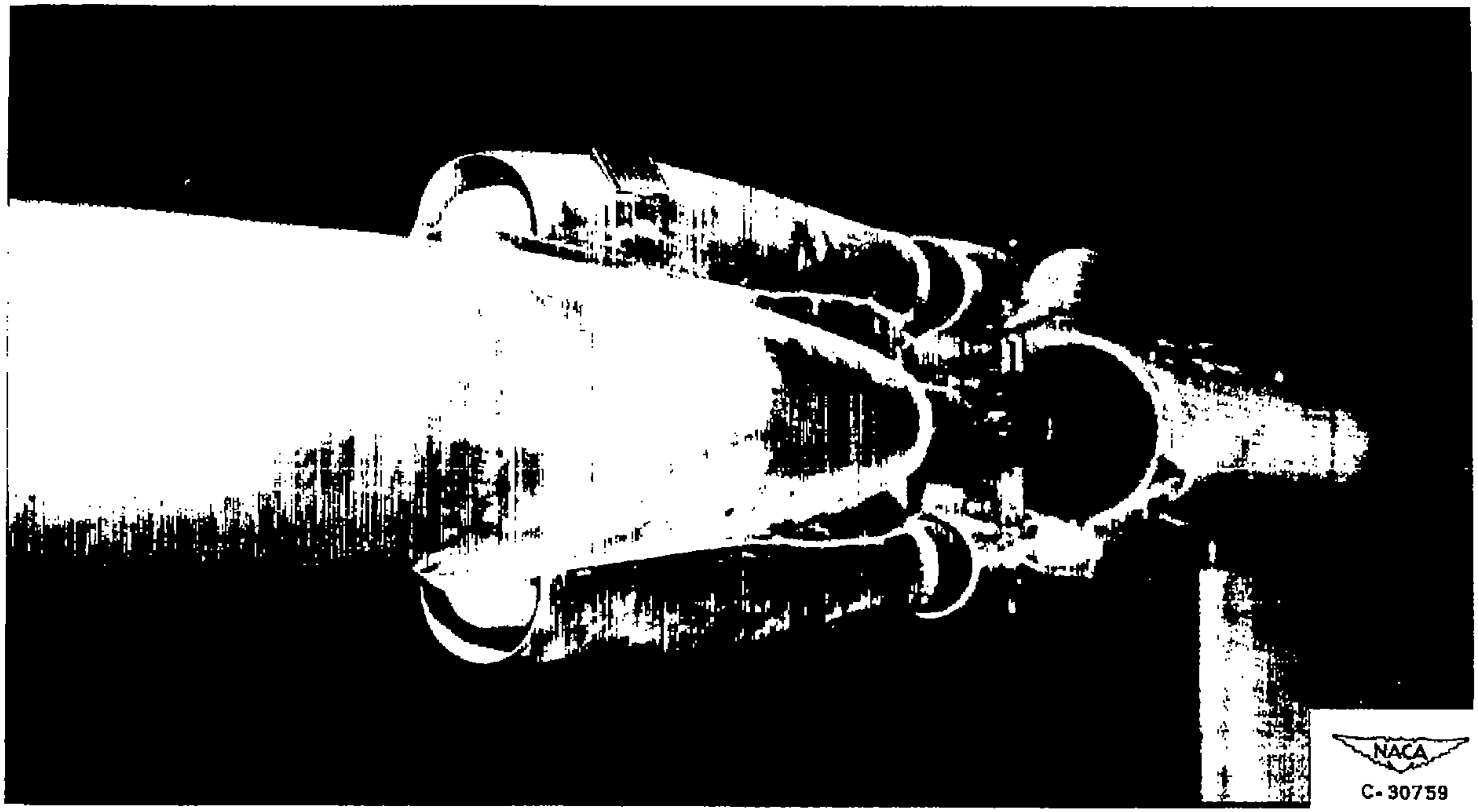

Figure 1. - Photograph of model.

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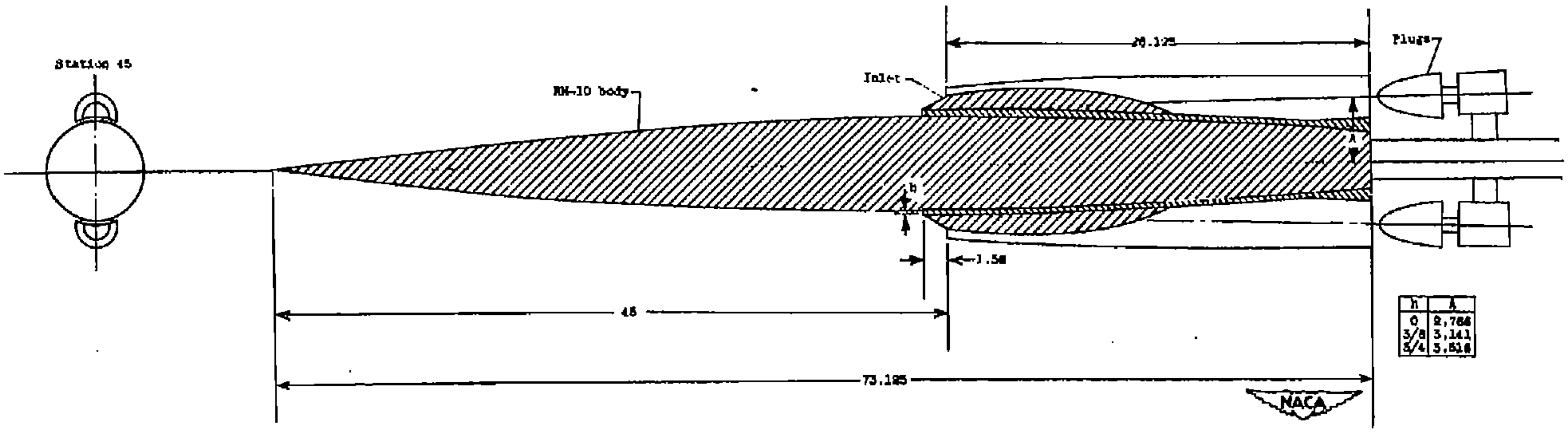

h	A
0	2,766
3/8	3,141
3/4	3,516

(a) Twin scoop inlets mounted on RM-10 body.

Figure 2. - Schematic diagram of model. (All dimensions are in inches.)

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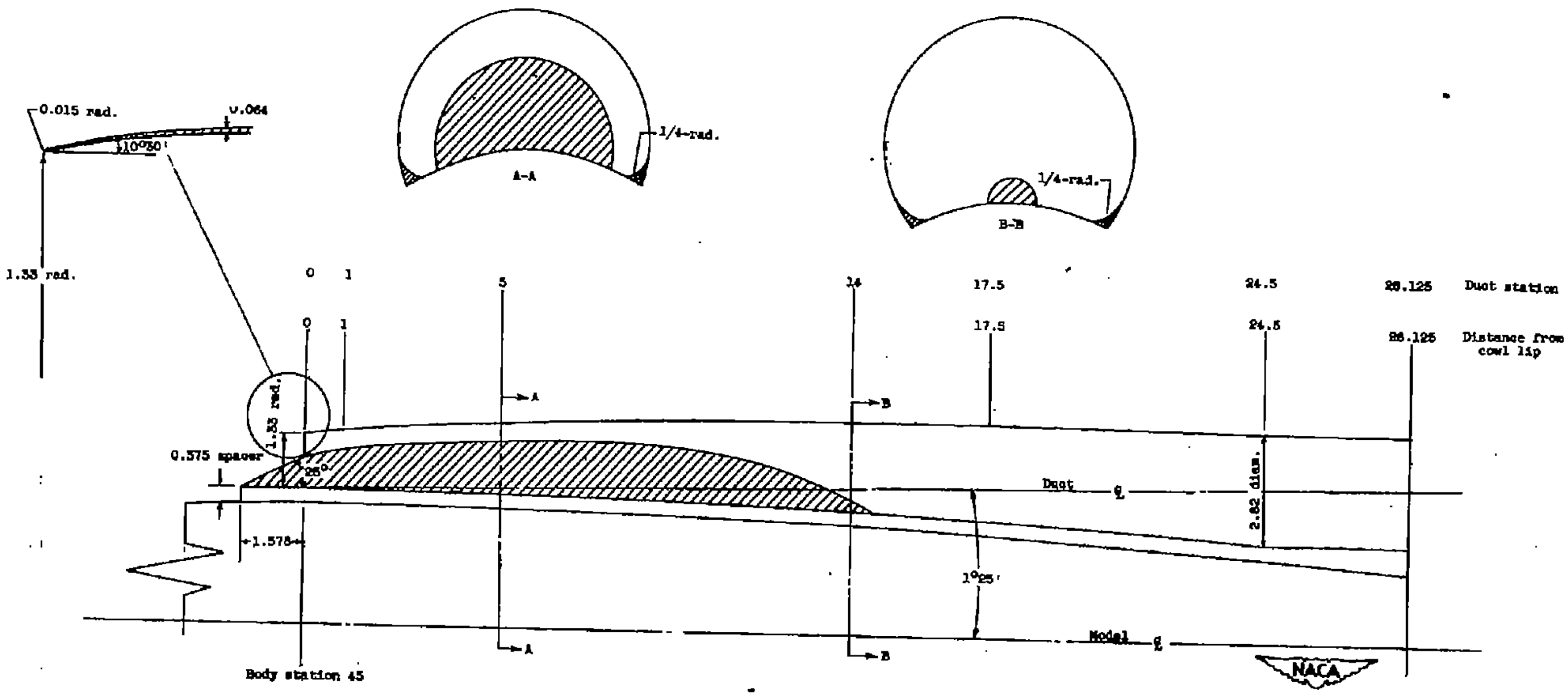

(b) Inlet.

Figure 2. - Concluded. Schematic diagram of model. (All dimensions are in inches.)

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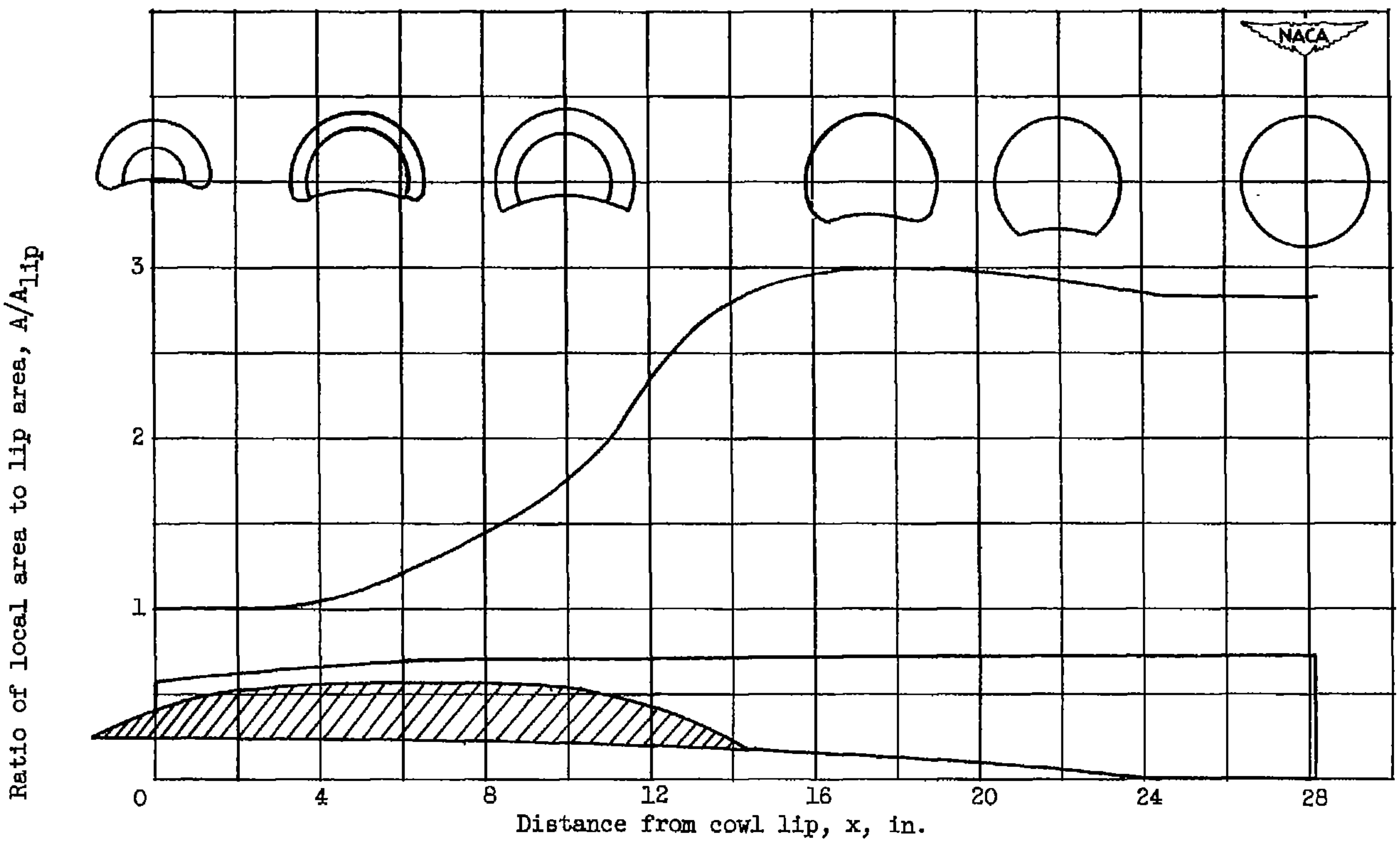

Figure 3. - Area variation of inlets.

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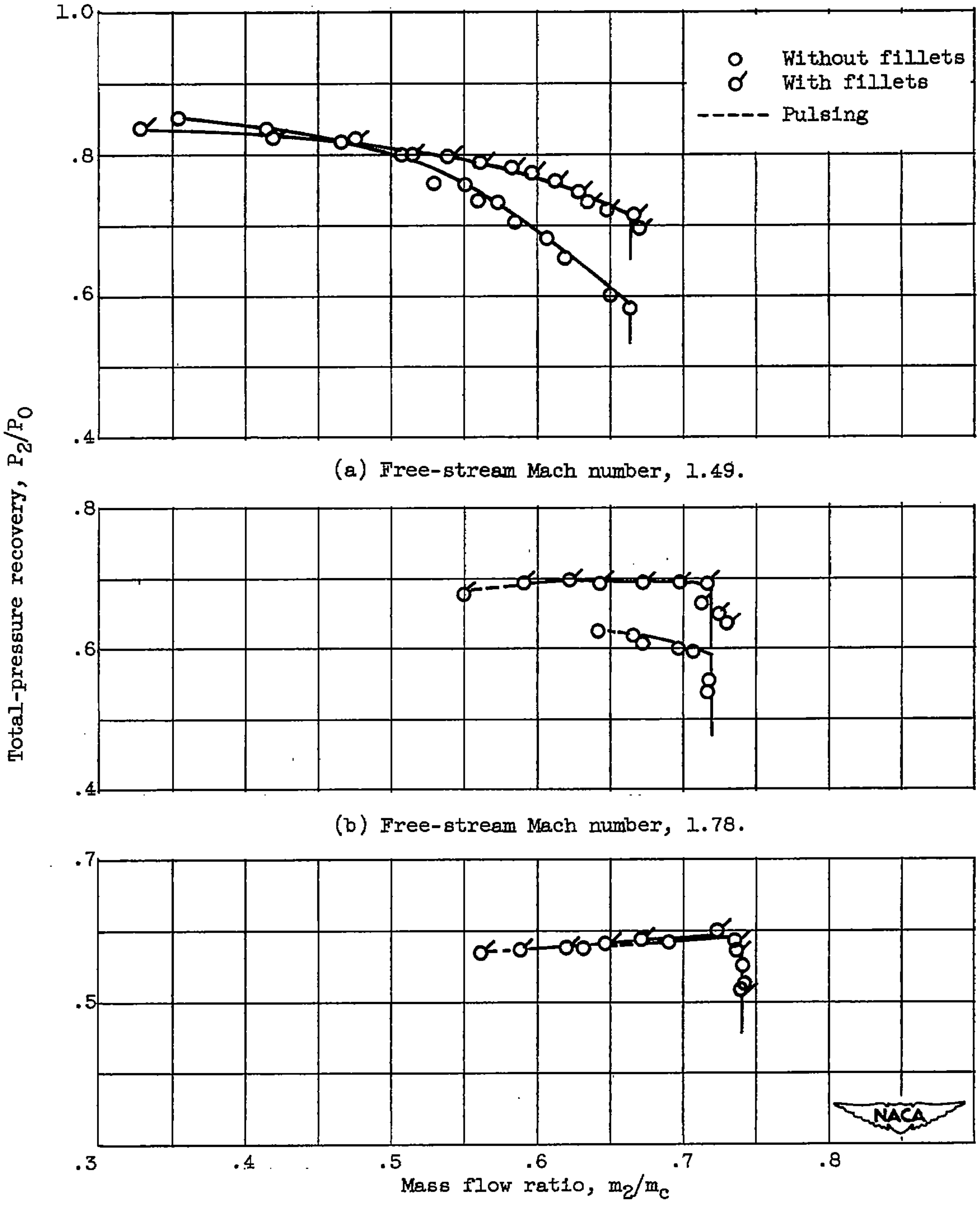
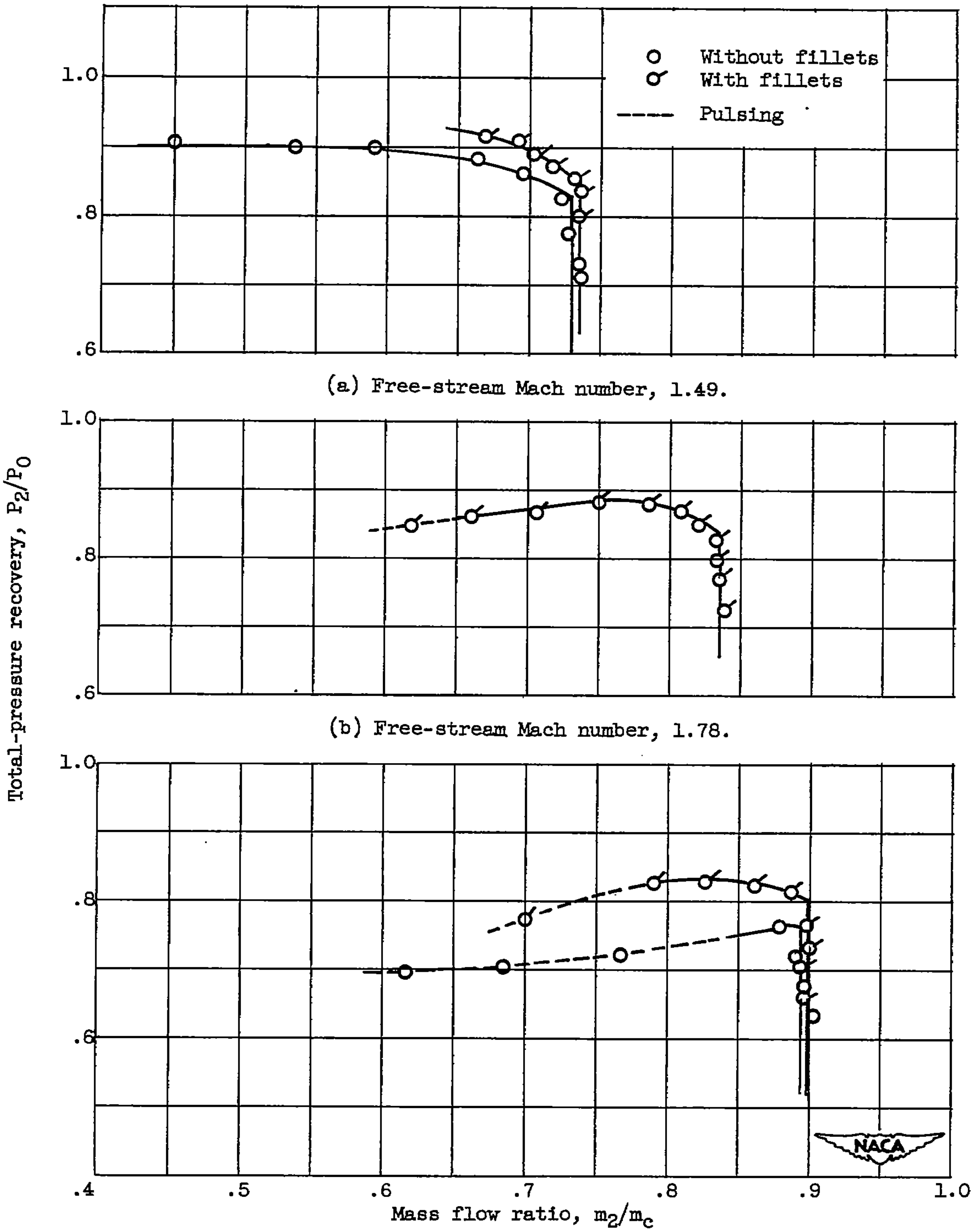


(a) Free-stream Mach number, 1.49.

(b) Free-stream Mach number, 1.78.

(c) Free-stream Mach number, 1.97.

Figure 4. - Mass flow - pressure recovery characteristics of inlets with and without corner fillets at free-stream Mach numbers of 1.49, 1.78, and 1.97 and zero angle of attack with boundary-layer removal parameter of 0.

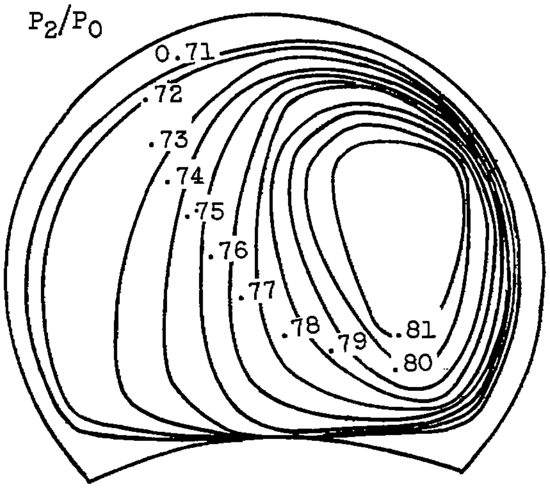


(a) Free-stream Mach number, 1.49.

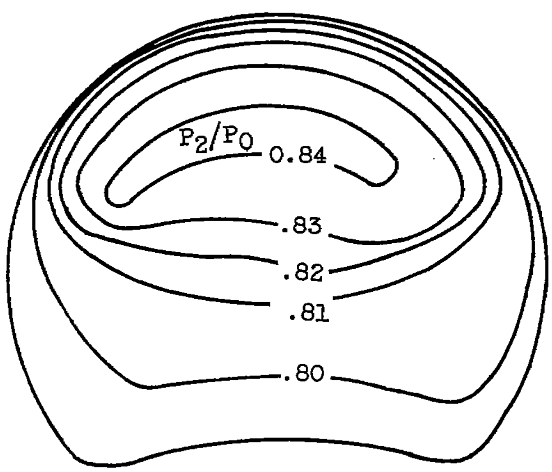
(b) Free-stream Mach number, 1.78.

(c) Free-stream Mach number, 1.97.

Figure 5. - Mass flow - pressure recovery characteristics of inlets with and without corner fillets at free-stream Mach numbers of 1.49, 1.78, and 1.97 and zero angle of attack with boundary-layer removal parameter of 1.0.

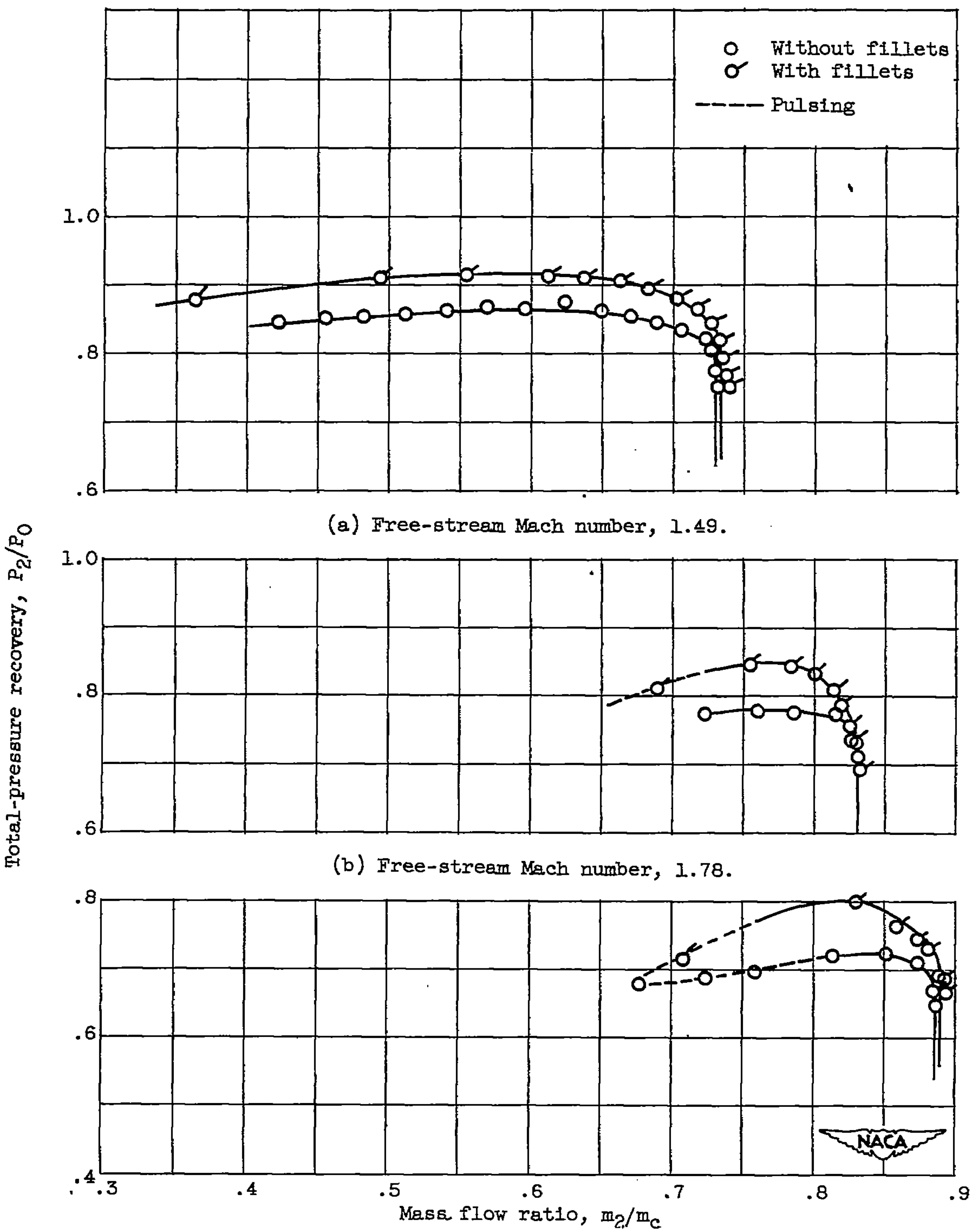


(a) Inlets without corner fillets. Static- to total-pressure ratio, 0.729; mass flow ratio, 0.880.



(b) Inlets with corner fillets. Static- to total-pressure ratio, 0.728; mass flow ratio, 0.887.

Figure 6. - Contour maps of total-pressure recoveries near critical mass flows for inlets without and with corner fillets operating at free-stream Mach number of 1.97 with boundary-layer removal parameter of 1.0.

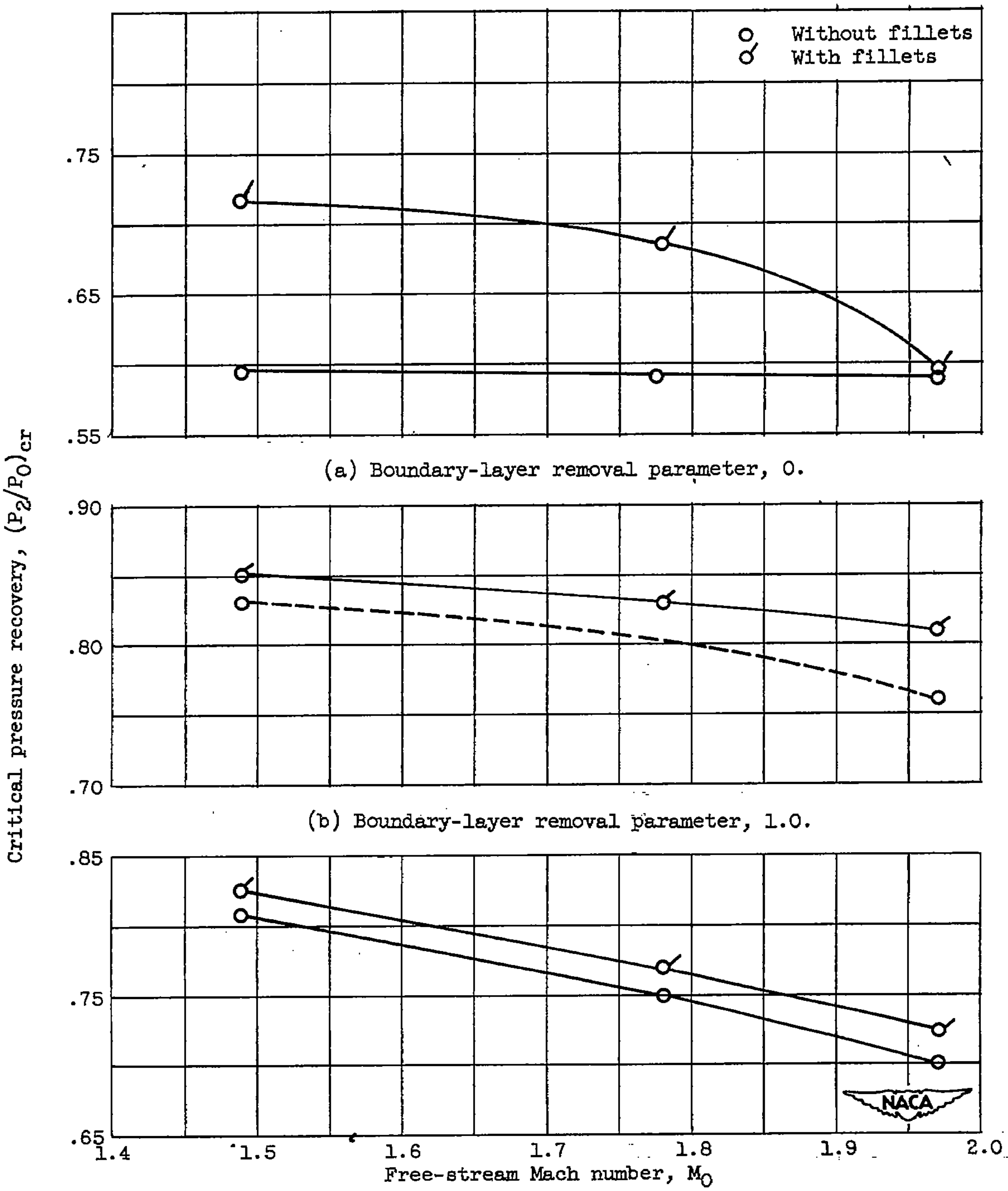


(a) Free-stream Mach number, 1.49.

(b) Free-stream Mach number, 1.78.

(c) Free-stream Mach number, 1.97.

Figure 7. - Mass flow - pressure recovery characteristics of inlets with and without corner fillets at free-stream Mach numbers of 1.49, 1.78, and 1.97 and zero angle of attack with boundary-layer removal parameter of 2.0.



(a) Boundary-layer removal parameter, 0.

(b) Boundary-layer removal parameter, 1.0.

(c) Boundary-layer removal parameter, 2.0.

Figure 8. - Comparison of pressure recoveries of inlets with and without corner fillets at critical mass flows for boundary-layer removal parameters of 0, 1.0, and 2.0.

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